CPF-CERES Intercalibration: Desirables/Expected Outcome

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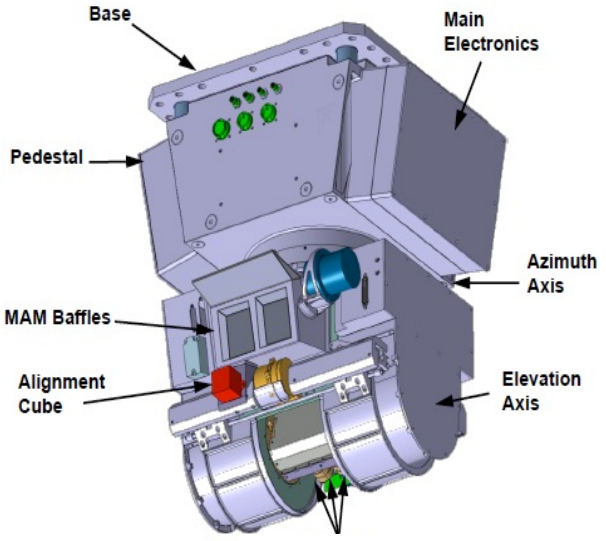
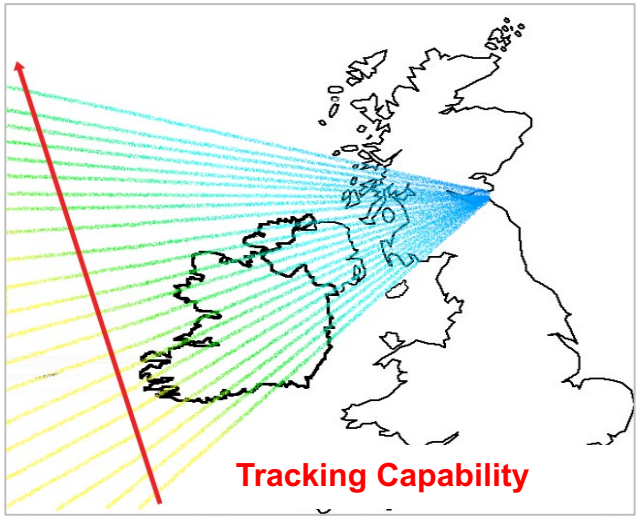
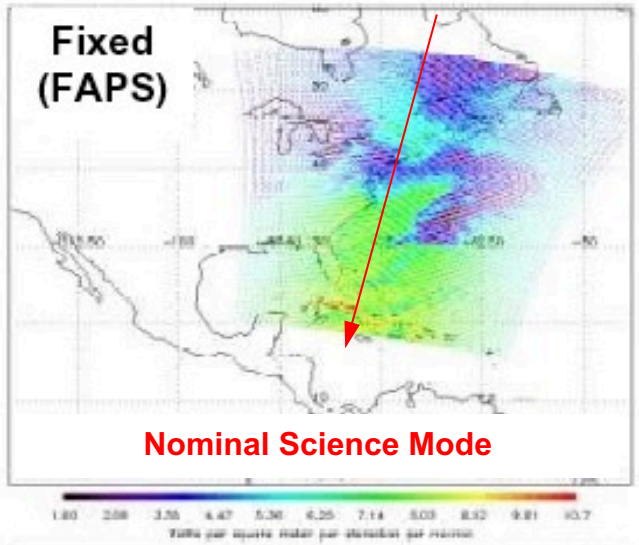
CERES Background

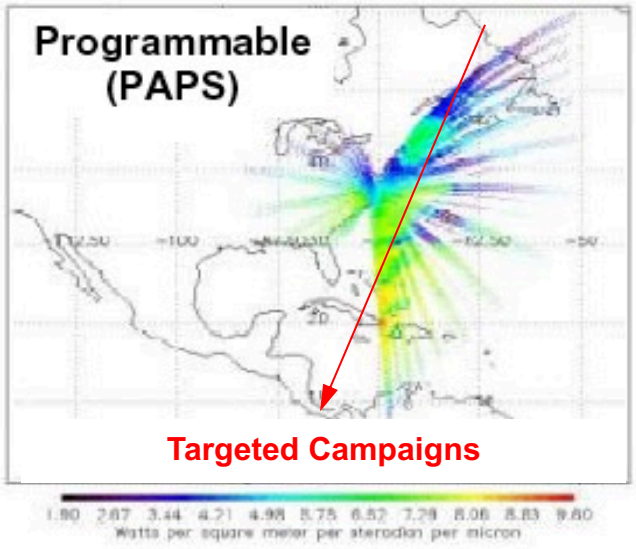
- CERES instrument enables measurement of the Reflected Solar and Outgoing LW radiation from the Earth's Top of the Atmosphere (TOA).
- CERES measures the radiation at the TOA with three channels:
  - SW: 0.3-5 μm
  - TOT: 0.3->100 μm
  - WN: 8-12 μm/LW: 5->50μm (FM6)
- Three telescopes are co-aligned and mounted on a spindle that can be rotated about the elevation axis.
- Instrument can also be rotated about the azimuth axis.
- Radiometric accuracy: 1% for SW and 0.5% for LW, for k=1.
- There are six CERES instruments currently operational:
  - FMs 1 and 2 on Terra, launched in Dec 1999.
  - FMs 3 and 4 on Aqua, launched in May 2002.
  - FM5 on S-NPP, launched in Oct 2011.
  - FM6 on NOAA-20, launched in Nov. 2017.

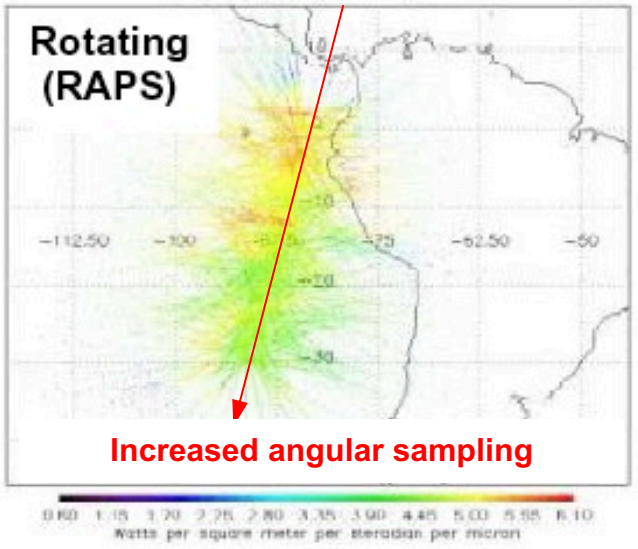


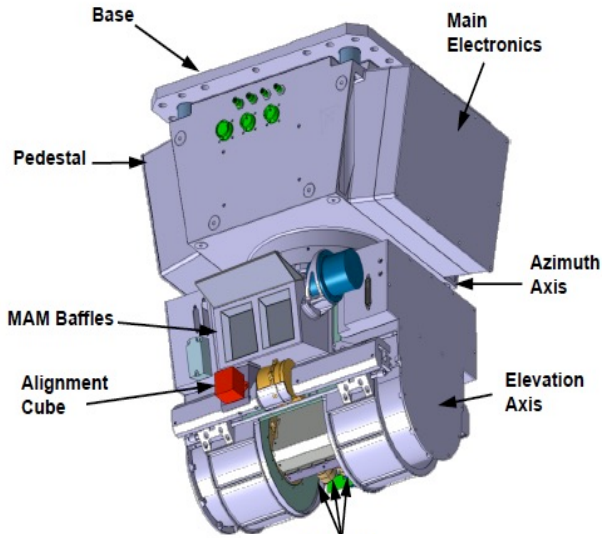
CERES Operational Scanning Capabilities







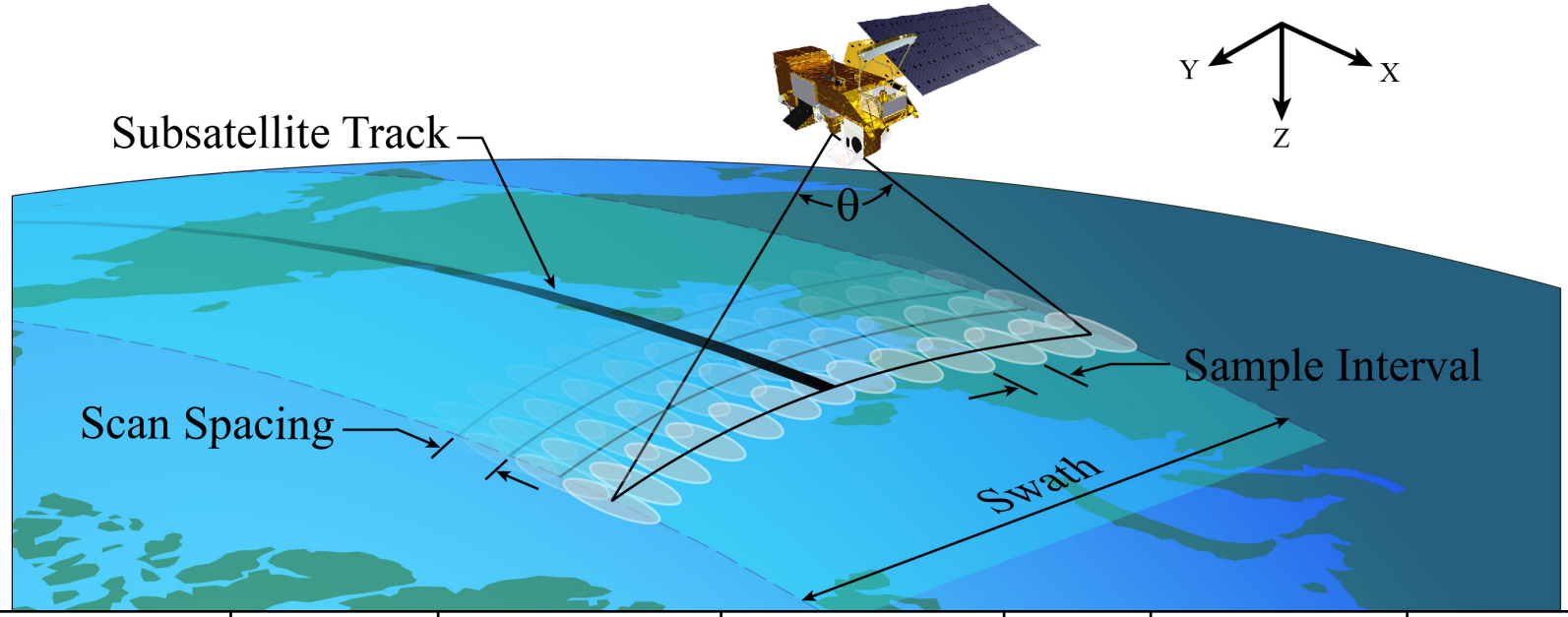




Sensors- TOT, SW, WN or LW (FM6)

APS: Azimuth plane Scan

CERES spatial sampling characteristics



Spacecraft	Altitude (km)	Equatorial crossing Mean Local Time	Viewing Range limb-to-limb, θ (deg)	Swath (km)	Scan Spacing at Nadir, 6.6 s interval (km)	Sample interval (km)
Terra	705	1030*	128.4	5739	49.5	7.8-40.2
Aqua	705	1330	128.4	5739	49.5	7.8-40.2
S-NPP/NOAA-20	824	1330	124.6	6161	49.1	9.1-41.2

*Currently drifting

Cross-track scan spacing driven by Scan Rate
Along-track spacing given by S/C motion and Scan Cycle Time

CERES On-orbit Calibration/Validation Protocol

		Product Level	Spatial Scale	Temporal Scale	Spectral Weighting	Dynamic Range	Latitude Range	Radiometric Metric	Channel	Product
On-Board	Internal BB	Filtered Radiance	Full IFOV	Continuous Capability	290-320 K BB	Across	All	Absolute Accuracy, Stability	TOT, WN, LW	-
	Internal Lamp	Filtered Radiance	Full IFOV	Continuous Capability	17000, 2000, 2300 K BB	Across	All	Absolute Stability	SW	-
	Solar	Filtered Radiance	Full IFOV	1 per orbit capability	Solar	Fixed, High	N or S Pole	Relative Stability	TOT, SW	-
Vicarious	Theoretical Line-by-Line	Filtered Radiance	>20 Km	Instantaneous	Various Earth	Across	N/A	Inter-Channel Theoretical Agreement	TOT, WN, LW	-
	Unfiltering Algorithm Theoretical Validation	N/A	N/A	N/A	N/A	N/A	N/A	N/A	TOT, SW, WN, LW	-
	Inter-Satellite (Direct Comparison)	Unfiltered Radiance	1-deg Grid	1 per crossing	Various Earth	Mid	All	Inter-Instrument Agreement, Stability	TOT, SW, WN, LW	OLR, RS
	Tropical Mean Geographical Average)	Unfiltered Radiance	20N-20S	Monthly	Tropical Ocean, All Sky	Mid	20N-20S	Inter-Instrument Agreement, Stability	TOT, WN	OLR
	DCC Albedo	Unfiltered Radiance	> 40 Km	Monthly	Cloud RS	High	All, Daytime	Inter-Instrument Agreement, Stability	SW	RS
	3-Channel Intercomparison	Unfiltered Radiance	>100 Km	Monthly	Various Earth	Across	All, Daytime	Inter-Channel consistency, Stability	TOT, SW, WN, LW	OLR, RS
	Time Space Averaging	Fluxes	Regional, Zonal, Global	Monthly, Yearly	Various Earth	Across	All	Inter-Instrument Agreement		OLR, RS
	Lunar Radiance Measurements	Filtered Radiance	Sub IFOV (7-10%)	1 day per lunar month	Lunar OLR and RS	Fixed, Low	N or S Pole	Relative Stability	TOT, SW, WN, LW	

CERES Instruments' Current Operational Status

- **Terra**:
  - FM1 (Cross track mode)
  - FM2 (Biaxial mode since Nov. 1, 2021).
- **Aqua**:
  - FM3 (Cross track mode)
  - FM4 (Biaxial mode since July 2021), SW channel non-functional since Apr 2005.
- **S-NPP**:
  - FM5 (Biaxial mode since October 2019)
- **NOAA-20**:
  - FM6 (Cross track mode)

CPF-CERES Intercalibration: Desirables

Co-located inter-comparisons between CERES and CPF when the orbits cross-over, to validate CERES SW channel performance.

Desired characteristics of the inter-comparisons

- Geographically diverse scenes spanning the spectral and dynamic range of the CERES SW channel.
- Span the spectral range of CERES SW channel to evaluate performance in various wavelength domains, including in the UV/blue regions.
- Span the dynamic range to evaluate gain, linearity, offsets.

Value to CERES

- Compare/tie NOAA-20/FM6 SW channel observations to the CPF radiometric reference.
- Validate S-NPP/FM5 (and, possibly, Terra/FM2) SW channel performance while operating in RAPS mode.
  - Prior experience with operating in RAPS mode with instruments on Terra and Aqua caused optical degradation to the SW channel due to telescopes pointing in the ram direction.

CPF-CERES Intercalibration: Desirables cont'd

Independent validation of inter-instrument differences across CERES SW sensors on various spacecraft.

Challenges with current approach:

- Inter-comparisons between CERES instruments are obtained from co-located CERES data obtained where the orbits cross-over.
  - For Terra/Aqua, Terra/S-NPP, Terra/NOAA-20, these cross-overs occur North of 70^{o} latitude.
- Direct inter-comparisons between CERES on S-NPP and NOAA-20 are not possible because they are positioned half an orbit apart in the same altitude and inclination.
- Comparisons can be performed with Aqua that under-flies both S-NPP and NOAA-20.

Value to CERES

CPF could provide an independent validation of differences being observed between instruments across various spacecraft.

- Between NOAA-20/FM6 and S-NPP/FM5.
- Could these be done directly with Terra or Aqua?